PRELIMINARY NOTES ON SOME IGNEOUS ROCKS OF JAPAN. VI[1]

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VI. QUARTZ-SYENITE AND COMENDITE FROM THE OKI ISLANDS

Introduction.—Our geological knowledge of the Oki Islands is derived in the first place from the late Dr. T. Harada,[2] Mr. B. Minari,[3] and others, and subsequently from the more detailed work of Mr. M. Yamakami.[4] The last author's report and geological map were published in 1896 by the Imperial Geological Survey of Japan, and many rock-specimens collected by him are preserved in the Survey collection. Among them, I have found some interesting alkalic varieties, many of which have not yet been described in Japan; and their occurrence in our country, especially near the coast of the sea of Japan, is very interesting from a petrological point of view. In the summer of 1911, I had an opportunity to visit the islands and to make a collection of several varieties of these interesting rocks. The following description is a preliminary account of the petrological observations made on my journey, and of the quartz-syenite and comendite, the most interesting rocks that I collected.

For the chemical analyses of these rocks, made in the laboratory of the Imperial Geological Survey of Japan, I am greatly indebted to Mr. K. Yokoyama, and my sincere thanks are due to Professor B. Koto, for advice and assistance in the study of the rocks.

[1] Published by permission of the Director of the Imperial Geological Survey of Japan.

[2] T. Harada, *Versuch einer geotectonischen Gliederung der japanischen Inseln*, Imp. Geol. Survey, Japan, 1888; T. Harada, *Die japanischen Inseln*, Imp. Geol. Survey, Japan, 1890.

[3] B. Minari, Explanatory Text to the Agronomic Map of Izumo, Iwami, and Oki Provinces (in Japanese), Imp. Geol. Survey, Japan, 1895.

[4] M. Yamakami, Explanatory Text to the Special Geological Map of the Section Oki (in Japanese), Imp. Geol. Survey, Japan, 1896.

Morphological sketch of the Oki Islands.—The Oki Islands, lying within 132° 56′–133° 22′ E. long. and 35° 56′–36° 20′ N. lat., are off the coast of Izumo, the northwestern province of Honshû, at a distance of about 65 kilometers. There are four main islands, in two groups. One large island called Dōgo is situated to the northwest, and is separated by a strait 12 kilometers wide from the other three smaller ones—Chiburi-shima, Nishino-shima, and Nakano-shima, together known as Dōzen. There are also 180 islets and rocks included under the name of the Oki Islands. The total land-area is about 351 square kilometers.

The coast line of Dōgo is rather regular, and its shape is roughly circular, indented by the bay of Saigō on the southeast and by the bay of Fuku-ura on the northwest. Many other smaller narrow inlets occur mostly on the southern coast. The coast line of Dōzen, however, is irregular and is detached into three islands by narrow channels called Ōguchi, Akanadaseto, and Nakaiguchi. These islands are arranged in a triangular position on the arc of a circle.

Dōgo has a length of about 21 kilometers from south to north and a little shorter breadth from east to west. Its area is about 245.6 square kilometers, and the coast, in great part, ends abruptly against the sea, with elevations varying from 30 meters to 100 meters. The island is mountainous and morphologically divisible into two parts, the western and eastern districts (Fig. 1), separated by a watershed trending nearly north and south through the middle of the island. The western region consists of gently sloping ridges (Fig. 1), composed of rhyolite flows, averaging 300 meters in altitude. These flows have been eroded to deep and narrow valleys diverging toward the west and southwest from two isolated peaks, called Ōmine (666 m.) and Yoko-o-yama (568 m.), which are situated on the watershed. It is evident that the region was formerly covered by almost horizontal rhyolite flows. The eastern district is characterized by ragged peaks and isolated knolls, composed of several kinds of rocks. The highest point on the conical mountain of trachydolerites, named Daimanji (Fig. 1), is 646 meters in altitude. The south and east ridges descend gradually, but the mountains to the north and west have precipitous slopes and are very irregular.

The most striking physical feature of Dōzen is the circular arrangement of the three main islands. The largest island, Nishino-shima (55.23 sq. km.), lies on the northwest of the group; the smaller one, Nakano-shima (35.20 sq. km.), on the east; and the smallest, Chiburi-shima (14.82 sq. km.), on the south. An inland sea with an area of about 51.24 square kilometers is inclosed by the three islands. The most prominent peak, called Takuhi-yama (Fig. 2), 525 meters in height, is situated south of the middle part of Nishino-shima. The sea coast facing the ocean ends abruptly, as is the case at Dōgo, and the slope of the islands is steeper toward the inner side than toward the outer. Dr. T. Harada compared the form of Dōzen with that of Santorin in the Mediterranean.

FIG. 1.—Dōgo as seen from the south

Geological sketch of the Oki Islands.—In order to give a general idea of the structure of the Oki Islands, their geological features will be described briefly. The geological formations of the islands, in the order of their age from younger to older, are as follows:

1. Alluvium.
2. Trachydolerites and basalts.
3. Diluvium (?).
4. Trachytes.
5. Trachyandesites and trachydolerites.
6. Trachytic rhyolites.
7. Greenish trachyandesites.
8. Soda-rhyolites.
9. Schistose granites and quartz-syenites.
10. Andesites.
11. Tertiary strata.

The islands consist mainly of volcanic rocks, which were erupted at several times, probably from the middle of the Tertiary

to the beginning of the Diluvium. Besides these extrusive rocks, there are intruded masses of granites, quartz-syenites and their allied porphyries, occurring in a limited area. It is highly probable that all these igneous rocks are younger than the bottom beds of the Tertiary, which make up the base of the islands.

At Dōgo, the Tertiary formation is met with in the southwestern and northeastern sea-cliffs overlaid by lava flows, and in the middle of the island, where the elevation is about 300 meters above the sea-level. It consists of tuffs, conglomerates, sandstones, and shales, in which deposit plant fossils are preserved. The formation is intruded by andesite sills and by schistose granites and their allied porphyries. It is folded and faulted, and its strikes and dips are variable in places, but the general dip is gentle.

At Dōzen, the Tertiary formation occurs in a small area and is free from andesite sills, so far as the writer's observation goes. But it is intruded by quartz-syenite and its apophyses, and at the place of contact, metamorphosed sandstone with abundant brown mica is exposed.

The age of the formation is considered to be Miocene, corresponding to that of the formation along the northwestern coast of Honshū.

The Diluvium is exposed near Tōgō, a small village in Dōgo. It consists of gravels and blocks of trachydolerites and trachytic rhyolites, and is overlaid by the younger trachydolerite flow. The outcrop is clearly seen at a new cutting, a little south of Tōgō. The formation seems to have been locally deposited in a lake, which now forms the bay of Saigō.

The Alluvium is river deposit, seen in a limited area along valleys. The description of

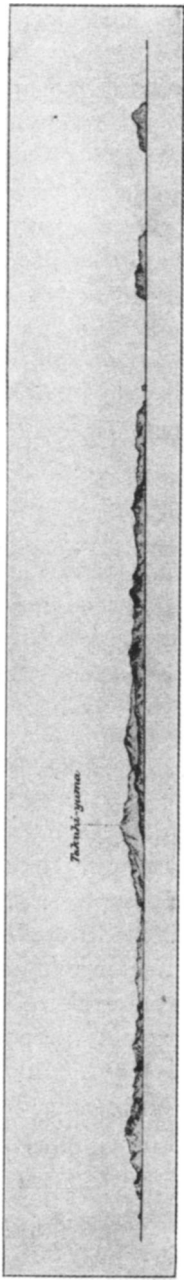

FIG. 2.—Dōzen as seen from the southeast

the geological relations of the igneous rocks[1] will be given with the petrographical notes of each kind of rock. However, some striking geological features may be mentioned. Enormous quantities of trachydolerites and trachyandesites were erupted near the end of the igneous activity in the region, and Dōzen was mainly composed of these rocks. Their eruptions seem to have occurred at several localities. After some interval of time there was a depression of the middle of the land which formed the inland sea already described. This movement fractured the ground greatly and gave rise to the eruption of trachytes. The rocks occur as flows and dikes; the flows form most prominently Takuhi-yama, and the dikes occur in very remarkable radial arrangement having Takuhi-yama as an approximate center, traversing trachydolerites, trachyandesites, and the Tertiary formation; but no dike was seen cutting the syenite mass. The occurrence of these dikes is analogous to that of the basic dikes in Rum, Scotland, described by Harker[2] and to that of the basaltic and trachytic dikes in the Highwood mountain, Montana, described by Pirsson;[3] though the petrographical character of the rocks and the number of the dikes are not the same.

QUARTZ-SYENITE

Field observation.—The rock is found in a small mass, only, at the northeastern foot of Takuhi-yama at Dōzen. It occurs intruded in the Tertiary formation and is covered by glassy trachytes which build up Takuhi-yama. Its contact action on the Tertiary rocks is clearly seen, and the metamorphosed shaly sandstone is permeated by a brown mica as a contact mineral. The endomorphic effect is not so pronounced as that observed in other countries where this rock type has been described by several authors. The texture becomes gradually fine-grained and inconspicuously porphyritic by the development of feldspar 1 cm. in average length. Hornblende, which occurs as an essential mineral in the main mass,

[1] The petrographical notes on several kinds of rocks from the islands are not described in this paper. They will be published in the report of the Imperial Geological Survey of Japan.

[2] Harker, *Memoirs of the Geological Survey, Scotland*, 1908, p. 143.

[3] Pirsson, *Bulletin No. 237, U.S. Geol. Surv.*, 1905, p. 20.

is almost entirely replaced by biotite in the fine-grained part. If the Tertiary formation, through which the syenite intrudes, proves to be Miocene as considered now, the syenite will be probably the youngest rock of this kind which has ever been described.

Megascopic character.—It is medium-grained, evenly granular, and almost compact, though miarolitic cavities are present. On a freshly fractured surface, the color is light gray with somewhat waxy luster. The rock consists mainly of feldspar, which is light gray, due to clouded, minute inclusions; and, in some crystals, a faint blue shiller is recognizable. Close examination shows certain feldspars developed with a more or less idiomorphic and thick tabular habit. Black hornblende occurs in moderate quantity, scattered through the feldspathic mass. Its form is irregular, but the general shape is prismoid with an average length of 3 mm. Biotite is quite subordinate in amount, and quartz is scarcely detected with a lens.

Microscopical character.—The constituent minerals present in the rock specimen used for a chemical analysis are quartz, alkali feldspar, plagioclase, hornblende, biotite, diopside, olivine, apatite, zircon, ilmenite, and magnetite; besides zeolites in miarolitic cavities. The amounts of diopside and olivine are variable even in specimens taken from very near one another. A thin section shows the presence of allanite. The rock consists essentially of feldspar with hornblende; and the other minerals, with the exception of allanite, are also constant ingredients, though their quantities are subordinate and variable. The texture, for the most part, is granitoid, but there are some peculiarities of micrographic intergrowth of feldspar and quartz and of miarolitic cavities.

The feldspars are mostly alkalic (orthoclase, microperthite, and cryptoperthite), but plagioclase is not rare. The latter mineral is represented by oligoclase and albite, which, besides perthite, is also found as the border of the alkali feldspar. The alkali feldspars are tabular, parallel to (010), and are variable in shape, some of them being irregularly contoured and others rather euhedral. They are clouded with dusty particles and frequently show the zonal structure due to chemical differences. The outer shell is usually thin and clear, in strong contrast to the clouded inner part. The former

show slightly higher refraction and birefringence than the latter. The extinction angle of the shell is $+10°$ on a section nearly parallel to (010), while the inner part shows $+7°$ on the same section. From these characters, the outer material must be referred to a variety of anorthoclase with especially high content of soda. Inclusions are plagioclase, sharply defined apatite, a few crystals of zircon, magnetite, and quartz. The last mineral appears micrographically intergrown in the peripheral part of the feldspar. No microcline structure is observed. The oligoclases usually occur in prismatic form and are, in many instances, included in the alkali feldspar. They show distinct polysynthetic lamellae and are clearer, owing to fewer inclusions, than those in the alkali feldspar. They vary in composition within a limited range, judging from their indices of refraction. Generally the refractions are slightly higher than those of quartz and Canada balsam and the maximum symmetrical extinction angle of a calcic variety exceeds $17°$.

The hornblende is mostly greenish-brown, associated with a bluish-green variety. Its form is irregular in general; sometimes more or less idiomorphic in elongated or short prismatic form. Cross-sections exhibit the characteristic cleavage and rhombic outline, or sometimes six-sided section elongated along the axis *b*, having the first pinacoid strongly developed and with the unit prism subordinate. The bluish-green variety occurs as fringes or borders, and as inclusions in the brown, and as an individual of quite irregular shape in very rare instances. In the first instance the green variety does not entirely inclose the brown, and in many instances it occurs on the terminal faces of the brown crystal. These two varieties exhibit almost no differences in optical orientation. They are strongly pleochroic: X, light yellow; Y, dark brownish-yellow; Z, greenish-brown to olive-green; absorption $Y>Z>X$, on the greenish-brown variety, and X, light yellow; Y, yellowish-green; Z, bluish-green; absorption $Z>Y>X$, on the bluish-green variety. They extinguish in nearly the same position and the angle between Z and c on (010) is from $26°$ to $28°$ in the obtuse angle B. From these properties, the hornblende seems to be barkevikite near katophorite or hastingsite, but it is not like it in the larger optical angle (?) and the higher birefringence.

Quartz is present in small amount as shown by the chemical analysis, but it is sufficient to characterize the rock as quartz-bearing syenite. It occurs interstitially, or intergrown micrographically, with the alkali feldspar, and frequently as an infiltration in miarolitic cavities with zeolite. In the last case, it often shows distinct euhedral outline.

Biotite is sparingly present, and usually occurs associated with hornblende. It is optically negative, and the plane of the optic axes lies in the plane of symmetry. The optical angle measured is $2E=36^\circ 23'$. The pleochroism is strong: X, brownish-yellow; Y, brown with violet tinge; Z, dark reddish-brown; and absorption, $Z>Y>X$. Magnetite and apatite are included in it.

The diopside shows an irregular form and is colorless or pale violet, being slightly pleochroic. Its quantity is variable and it shows a tendency to replace hornblende. Olivine occurs in more or less automorphic outline, and is quite fresh. It is almost free from inclusions with the exception of a few minute crystals of magnetite and apatite. The ilmenite and magnetite are present in association with each other. The former is in irregular form and is characterized by the decomposed product, leucoxene. Apatite occurs conspicuously in elongated prismatic form. It is comparatively abundant.

The mineral described here as allanite is not exactly determinable, owing to its rare occurrence and deep color, in some instances being almost opaque. It is strongly pleochroic from deep reddish-brown to opaque. In some respects, it resembles aenigmatite or rhönite. Its form is long prismatic with irregular terminations. Zonal structure is not recognizable, and cleavage is also indeterminable. One section observed is cut nearly perpendicular to an optic axis, its cross-bar appearing in the middle of the field. The case is very similar to that of the allanite-like mineral in the Mt. Belknap syenite, described by Pirsson and Washington. The characters of the mineral will be determined after further examination of more thin sections.

Chemical character.—The analysis of the rock, collected from the eastern foot of Takuhi-yama, Ezirigasaki, Kuroki-mura, Dōzen, was made by K. Yokoyama in the laboratory of the Survey. It is given

in column A. in the following table. Compared with foreign rocks, the rock from Oki has a close resemblance to the akerite-porphyry, described by Brögger;[1] the augite-syenite, described by Cushing;[2] the quartz-syenite, described by Pirsson;[3] and the syenite, described by Pirsson and Washington.[4] It differs from the pulaskite from Fourche Mountain, described by Williams[5] and by Washington[6] respectively, in having less alumina, less alkalies, and more iron oxides. These relationships are shown in the following table:

	A	B	C	D	E	F	G
SiO_2	61.83	62.60	63.45	65.54	60.75	60.25	60.03
Al_2O_3	17.08	18.07	18.31	17.82	19.68	20.40	20.76
Fe_2O_3	2.14	2.28	0.42	0.74	1.54	1.74	4.01
FeO	2.71	2.25	3.56	1.15	2.98	1.88	0.75
MgO	0.89	1.16	0.35	0.98	0.81	1.04	0.80
CaO	2.24	2.27	2.93	1.92	2.29	2.00	2.62
Na_2O	4.93	5.45	5.06	5.55	4.89	6.30	5.96
K_2O	5.37	5.22	5.15	5.58	5.90	6.07	5.48
H_2O+	1.60*	0.50	0.30	0.54	0.08	0.23	0.53
H_2O-	....	....	....	....	0.24	0.10	0.06
TiO_2	0.30	....	0.07	0.11	0.63	0.14	....
ZrO_2	....	....	....	....	....	trace	....
P_2O_5	0.35	....	trace	....	trace	0.15	0.07
SO_3	....	....	....	....	....	0.13	....
MnO	0.12	....	none	trace	trace	trace	trace
BaO	....	....	0.13	....	....	....	....
Li_2O	....	....	....	trace	....	....	....
Total	99.56	99.84	99.73	99.92	99.79	100.47	101.07

* Loss on ignition.

A. Quartz-syenite from the eastern foot of Takuhi-yama, Dōzen, Oki. K. Yokoyama, analyst.

B. Åkerite-porphyry from Ullernas, Norway. G. Forsberg, analyst.

C. Augite-syenite from Loon Lake, Franklin County, N.Y. E. W. Morley, analyst.

D. Quartz-syenite from Highwood Peak, Highwood Mountain, Mont. Pirsson and Michell, analysts.

E. Syenite from the western slope of Mt. Belknap, N.H. H. S. Washington, analyst.

F. Pulaskite from Fourche Mountain, near Little Mountain, Ark. H. S. Washington, analyst.

G. Pulaskite from Fourche Mountain, near Little Mountain, Ark. R. N. Brackett, analyst.

[1] Brögger, *Zeitschrift für Krystallographie*, XVI (1890), 49.

[2] Cushing, *Bulletin of the Geol. Society of America*, X (1899), 183.

[3] Pirsson, *Bulletin No. 237, U.S. Geol. Surv.*, 1905, p. 63.

[4] Pirsson and Washington, *American Journal of Science*, XXII (1906), 446.

[5] Williams, *Ann. Rep. of the Geol. Surv., Arkansas*, II (1890), 70.

[6] Washington, *Journal of Geology*, IX (1899), 1901.

Norms, calculated from the analyses, are as follows:

	A	B	C	D	E	F	G
Quartz	6.1	3.2	5.2	6.1	2.0	....	....
Orthoclase	31.7	31.1	31.1	32.8	35.0	36.1	32.8
Albite	41.9	46.6	42.4	47.2	41.4	41.0	45.6
Anorthite	8.6	8.9	11.7	7.2	11.4	9.2	13.3
Corundum	....	....	....	....	1.0	....	....
Nepheline	....	....	....	....	....	6.2	2.6
Diopside	....	2.1	2.2	1.9	....	0.8	....
Hypersthene	5.8	4.2	6.0	3.1	5.3	....	....
Olivine	....	....	....	....	....	3.1	1.4
Magnetite	3.0	3.2	0.7	1.2	2.1	2.6	2.6
Hematite	....	....	....	....	....	....	3.2
Ilmenite	0.6	....	....	....	1.2	0.3	....
Apatite	1.0	....	....	....	....	....	....

The ratios of the rock from Oki are as follows:

$$\frac{Sal}{Fem} \ldots\ldots 8.49$$

$$\frac{Q}{F} \ldots\ldots 0.07$$

$$\frac{K_2O'+Na_2O'}{CaO'} \ldots\ldots 4.42$$

$$\frac{K_2O'}{Na_2O'} \ldots\ldots 0.71$$

By the Quantitative System, the rock may be classified as pulaskose, near lauvikose.

As will be seen from the above description, the present rock is chemically close to acidic åkerite, that is, pyroxene-syenite, but it has mineralogically and chemically a close relation to the syenite from Belknap Mountain, New Hampshire. The petrographical characters of the rock show also some relation to normarkite on the one hand and to umptekite on the other. So it is concluded that the Oki rock is characterized, by mineralogical and chemical properties intermediate with respect to nordmarkite, umptekite and åkerite, though it is nearer to the last type.